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UTILIZATION OF GROUND WATER IN CALIFORNIA

By T. Russel Simpson, M. ASCE

IRRIGATION DIVISION

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Technical Division	*Proceedings-Separate Number*
Air Transport	42, 43, 48, 52, 60, 93, 94, 95, 100, 103, 104 (Discussion: D-XXVIII, D-7, D-16, D-23, D-18, D-43)
City Planning	58, 60, 62, 64, 93, 94, 99, 101, 104, 105 (Discussion: D-16, D-23, D-43)
Construction	43, 50, 55, 71, 92, 94, 103 (Discussion: D-3, D-8, D-23, D-17, D-36, D-40)
Engineering Economics	46, 47, 62, 64, 65, 68, 69, 95, 100, 104 (Discussion: D-2, D-19, D-27, D-30, D-36)
Engineering Mechanics	41, 49, 51, 54, 56, 59, 61, 88, 89, 96 (Discussion: D-5, D-XXIII, D-XXV, D-18, D-24, D-33, D-34)
Highway	43, 44, 48, 58, 70, 100, 105 (Discussion: D-XXVIII, D-7, D-16, D-23, D-13)
Hydraulics	50, 55, 56, 57, 70, 71, 78, 79, 80, 83, 86, 92, 96 (Discussion: D-XXVII, D-9, D-11, D-19, D-28, D-29)
Irrigation	46, 47, 48, 55, 56, 57, 67, 70, 71, 87, 88, 90, 91, 96, 97, 98, 99, 102 (Discussion: D-XXIII, D-3, D-7, D-11, D-19, D-25-K, D-29, D-17, D-30, D-38, D-40, D-44, D-47)
Power	48, 55, 56, 69, 71, 88, 96, 103 (Discussion: D-XXIII, D-2, D-3, D-7, D-11, D-19, D-25-K, D-17, D-30, D-38, D-40, D-44)
Sanitary Engineering	55, 56, 87, 91, 96 (Discussion: D-10, D-29, D-37)
Soil Mechanics and Foundations	43, 44, 48, 94, 102, 103 (Discussion: D-4, D-XXVIII, D-7, D-43, D-44)
Structural	42, 49, 51, 53, 54, 59, 61, 66, 89, 100, 103 (Discussion: D-5, D-3, D-8, D-16, D-23, D-13, D-21, D-24, D-25-K, D-32, D-17, D-33, D-34, D-39, D-42, D-37)
Surveying and Mapping	50, 52, 55, 60, 63, 65, 68
Waterways	41, 44, 45, 50, 56, 57, 70, 71, 96 (Discussion: D-XXVII, D-9, D-8, D-19, D-27, D-28)

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AMERICAN SOCIETY OF CIVIL ENGINEERS

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PAPERS

UTILIZATION OF GROUND WATER IN CALIFORNIA

By T. Russel Simpson,[1] M. ASCE

Synopsis

Great quantities of ground water are used for irrigation in the State of California. The paper traces the development of this ground-water utilization and gives detailed descriptions of the use of ground water in the major hydrographic areas of the state. Ultimate development is also treated in terms of unused ground-water storage areas and more efficient use of areas already developed.

Ground-Water Utilization

Utilization of ground water for irrigation was unimportant in California prior to 1880, except in Los Angeles and San Bernardino Counties, where nearly 1,000 flowing artesian wells had been developed prior to that time. In 1880 the total area under irrigation in various sections of the state from both surface and ground-water supplies was estimated to be as follows:

Location	Irrigated acreage
Southern California	82,500
San Joaquin Valley	188,000
Sacramento Valley	13,400
Sierra foothill valleys	9,000

The total irrigated area in the state in 1950 was almost 6,000,000 acres and more than 90% of the total water utilization in the state at that date was for irrigation purposes.

The total gross pumpage of ground water in California in 1950 was estimated to be about 10,000,000 acre-ft or about 40% of the total in the United States. The total diversion of surface waters, including the Colorado River, for irrigation, domestic, and industrial uses in California approximated ground-water extractions. A discussion of ground water utilization in various areas of the state of California is most conveniently broken down into the 7 major hydrographic areas shown in Fig. 1.

Note.—Written comments are invited for publication; the last discussion should be submitted by **May 1, 1952.**

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1. *South Coastal Area.*—The south coastal area embraces the drainage basins tributary to the Pacific Ocean from Ventura County to San Diego County, inclusive. The average annual combined runoff in these drainage basins for the 53-yr period 1894–95 to 1946–47 was slightly more than 1,000,000 acre-ft, or about 1.7% of the total runoff for the state. It is estimated that additional importations, over and above existing rights in the Colorado River, Owens River Basin, and Mono Basin will be required ultimately for development in south coastal area.

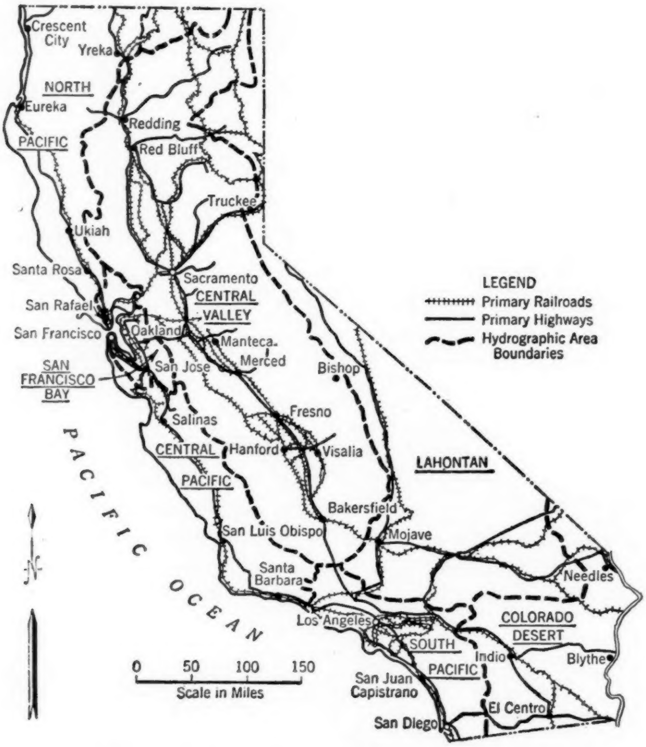

FIG. 1.—MAJOR HYDROGRAPHIC AREAS OF CALIFORNIA

Annual ground-water uses in the south coastal area amounted to about 800,000 acre-ft in 1950 and are nearly double those from surface supplies, including importations from the Colorado River, Owens Valley, and Mono Basin. Los Angeles County has for many years been the leading county in the United States in income from agricultural production. This production is supported largely by irrigation from ground water. Some 120,000 acres in Ventura County are devoted to high value crops and urban development. Water service for this area is largely dependent on ground water. There is some ground-water overdraft and evidence of sea water intrusion in wells near the ocean in which water levels fall below sea level in a series of dry years.

The habitable area in this county is about 70% developed. Additional water supplies will be required to eliminate overdraft and provide water to meet probable ultimate requirements in Ventura County.

The West Coast Basin lies between the Inglewood fault and the ocean, and extends from the Santa Monica Mountains to Long Beach in western Los Angeles County. Marine intrusion resulting from long-standing overdraft threatens to destroy the usability of this ground-water basin.

About 600,000 acre-ft of water are being pumped annually from the ground water of the Los Angeles, San Gabriel, and Santa Ana river systems. In 1950 there was an annual overdraft of about 45,000 acre-ft on ground water in the San Gabriel and Santa Ana river basin systems. Roughly 2,000,000 acre-ft of water is stored in a 50-ft zone below the water levels that existed at that time in the upstream basins, and while this is not a part of the permanent supply, it is available for emergency use pending a permanent solution of the problem. Maintenance of salt balance requires that some water be wasted, but the balance is a function of the water passing through the basin rather than the amount in storage. Industrial wastes and oil well brines have contaminated portions of ground-water basins in Los Angeles and Orange counties.

About 100,000 acres in the coastal drainage of San Diego County are devoted to high-value irrigated crops and urban developments. There is a large additional area suitable for irrigation and domestic occupancy in the county, and the ground-water basins comprise only a small part of the area. They are narrow and shallow in the upper reaches, and near the ocean the usable storage capacity is limited by the threat of sea water intrusion. Their effectiveness as regulators of the widely varying runoff is small. Roughly one third of the present water supply is derived from ground water in San Diego County. The San Diego County Water Authority imported about 70,000 acre-ft of water from the Colorado River in 1948, of which the City of San Diego received about 50,000 acre-ft.

2. *Colorado Desert.*—The principal ground-water development in California within the Colorado River Basin is in Coachella Valley, northwest of Salton Sea. The gross pumpage of ground water in Coachella Valley has been approximately 100,000 acre-ft annually. Service by a supplemental surface water from the Colorado River was extended to this area in 1949. The valley fill in Imperial Valley is chiefly silt and compacted sands of low permeability, and there is essentially no irrigation from wells. The ground-water problems south of the Salton Sea are those of drainage due to high water table.

3. *Lahontan Basin.*—Antelope Valley is situated in the southwest portion of the Lahontan Basin. It embraces about 500,000 acres of valley land, half of which is irrigable land of good quality. With about 50,000 acres under irrigation from ground water in 1947, the annual overdraft of water was estimated to be 50,000 acre-ft. This will doubtless increase materially, but there is no local supply available for development to meet present deficiencies and provide water for anticipated expansion. However, the empty underground storage capacity is large.

Mojave Valley ground-water basin is situated east of Antelope Valley. Mojave River inflow to the valley averages about 80,000 acre-ft annually,

about 80% of which percolates and is retained in the ground-water basin. It is estimated that about 40,000 acre-ft per year is wastefully consumed by native vegetation on the low lands along the river. There is ample irrigable land within easy reach to utilize the available supply, but only a small part of it is irrigated.

The City of Los Angeles, during the three dry years 1929 to 1931, inclusive, pumped about 340,000 acre-ft from ground-water basins in Owens Valley for export through the Owens Valley Aqueduct. There have been no extractions for export since 1931, and the ground-water basins are now fully recharged. The glacial moraine and lava sand deposits south of Mono Lake in Mono Basin appear to contain substantial undeveloped ground waters.

Ground-water draft is light in the remainder of the Lahontan Basin, although there are a number of domestic and stock-watering wells in shallow valley fills between Mono Lake and Honey Lake. There are also about a dozen irrigation wells in the Susan River delta and a few flowing wells on the west side of Suprise Valley that supply a limited amount of irrigation water.

4. *Central Coastal Area.*—The central coastal area embraces the drainage basins tributary to the ocean from San Francisco County to Santa Barbara County, inclusive. The combined mean annual runoff from these drainage areas approximates 2,000,000 acre-ft. A large part of the domestic, industrial, and irrigation development is dependent on underlying ground waters for its water supply. The draft on several of the major ground-water basins in the area has been so heavy that serious problems have arisen in respect to their adequacy, not only for future developments but also for maintaining the existing economy. Water levels at wells close to the coast have fallen to elevations below sea level in Pajaro, Salinas, and Arroyo Grande Valleys and on the south coastal plain of Santa Barbara County. Progressive lowering of water levels is occurring in Santa Ynez, Santa Maria, San Benito, and south Santa Clara Valleys.

The annual gross pumpage of ground water in the central coastal area approximated 600,000 acre-ft in 1950, about 60% of which is in Salinas Valley. The annual overdraft in Salinas Valley at that time was approximately 30,000 acre-ft, and the ultimate may approach 76,000 acre-ft. Small overdrafts also exist in Pajaro and south Santa Clara Valleys. Safe yield and overdraft estimates have not been made in the other ground water basins in the central coastal area. Unused underground storage and surface reservoir sites are generally available for salvage of such surpluses on the various stream systems as may be needed under ultimate development to supplement existing water supplies.

5. *San Francisco Bay Area.*—The San Francisco Bay area embraces portions of nine counties that drain into San Francisco, San Pablo, and Suisun Bays. The total average annual unimparied runoff from the drainage basins in the area in 1950 approximated 1,240,000 acre-ft. Twenty-two surface reservoirs with a combined capacity of about 400,000 acre-ft have been constructed in the area. Five of these in Santa Clara County, with a combined capacity of 43,100 acre-ft, are operated in conjunction with spreading works to

recharge ground waters. Additional reservoirs will provide an aggregate capacity of 106,000 acre-ft, all in Santa Clara County.

Ground waters are utilized to the extent of about 300,000 acre-ft annually in the San Francisco Bay area. Ground-water uses in the area surrounding the south bay in San Mateo, Santa Clara, and Alameda Counties exceed the safe yield. The annual deficiency in Santa Clara Valley in 1950 approximated 38,000 acre-ft and ultimately may approach 100,000 acre-ft.

The ground-water resources underlying about 60,000 acres along the eastern bay shore in southern Alameda County are threatened with destruction through depletion of underground storage and deterioration in quality. Proximity to the bay, water levels at wells prevailing materially below sea level, and decreasing amounts of chlorides easterly from the bay strongly suggest sea water intrusion into the ground-water resources of the Niles Cone area. The Alameda County Water District provides some artificial recharge by ponding for absorption.

Delivery of water through the Contra Costa Canal, a unit of the Central Valley Project, will provide adequate supplemental water to the Contra Costa Water District to meet probable ultimate water requirements in that area. The canal could, with storage constructed en route, be extended to furnish additional water supplies to the Richmon-Pinole area.

Small overdrafts exist in 1950 in the limited ground-water basins in the vicinity of Suisun and Fairfield in Solano County. The ground-water problems in Napa County have been relieved by construction of the Conn Valley and Rector Creek reservoirs with an aggregate capacity of 34,400 acre-ft.

Water is imported to the San Francisco Bay area from three sources: (1) Hetch Hetchy system on the Tuolumne River by the City of San Francisco; (2) Pardee Reservoir on the Mokelumne River by the East Bay Municipal Utility District; and (3) The Sacramento-San Joaquin delta, through the Contra Costa Canal, by the Bureau of Reclamation (USBR), United States Department of the Interior. These three systems, completely developed, could provide a total importation of about 900,000 acre-ft annually.

6. *North Coastal Area.*—The north coastal area embraces about 16,000 sq miles and this area yields about three eights of the total runoff of the state. The average runoff for the 53-yr period 1894–95 to 1946–47 approximated 29,000,000 acre-ft. The Mattole River, tributary to the ocean about 37 miles south of Eureka, has a water supply about equal to the combined runoff from all drainage basins in the previously mentioned south coastal area.

The combined ground-water uses in the north coastal area were on the order of 50,000 acre-ft annually in 1950. Use of ground water for irrigation was restricted to comparatively small areas in Santa Rosa Valley, Eel River delta, and Butte Valley in Siskiyou County. A limited amount of ground water is also used for domestic and municipal purposes.

7. *Central Valley.*—Utilization of ground water for irrigation in the Central Valley did not become significant until after 1900. More or less complete direct diversion of surface water supplies during the summer season in south San Joaquin Valley prior to 1910 gave impetus to development of ground water.

The combined capacity of wells in the San Joaquin Valley south of Chowchilla was about 7,300 cu ft per sec by 1919 and about 20,600 cu ft per sec by 1929. Overdrafts on ground water occurred in much of the area prior to 1929 and have prevailed since that time. Estimated usable underground storage capacity of approximately 20,000,000 acre-ft has made the long-continued overdraft possible. Depletion of underground storage generally has been severe on the west side of south San Joaquin Valley, in the Edison-Arvin area, and on the east side between Dinuba and McFarland. Water levels are generally high in the Kings River and Kern River service areas. Average water levels between 1939 and 1947 underlying 250,000 acres in the Kings River service area were less than 10 ft below ground surface, causing losses by evapo-transpiration to occur directly from the water table.

The combined gross pumpage of ground water from about 35,000 wells in the San Joaquin Valley (south of Merced River) during the seasonal year ending April 1, 1948, is estimated as being close to 6,000,000 acre-ft, or about 60% of the total in the state. The combined pumpage of ground water in that year in the lower San Joaquin Valley approximated 1,000,000 acre-ft. General extension of electric energy to the ground water basins and development of deep-well turbine pumps were important factors enabling ground-water utilization since 1925.

The annual pumpage of ground water in the Sacramento Valley, that embraces a gross area of about 6,000 sq miles or one-third of the Central Valley was about 1,000,000 acre-ft annually in 1950. Heavy pumping in the Peach Bowl area in Sutter County and in portions of the counties of Yuba and Placer has induced problems of localized overdrafts. Problems caused by the quality of water have been noted in the Coche Creek and Sutter Basin areas. During the 9-yr period from 1940 to 1948 the water table was perennially less than 10 ft below ground surface over an area of about 780,000 acres in the Sacramento Valley. The Sacremento River, and its tributaries throughout most of the ground-water basin drain surplus ground waters into the Sacramento-San Joaquin Delta. The irrigable land in the Sacramento Valley is only about one-third developed so use of ground water there can be expected to increase as long as its development can complete favorably with the cost of supplemental surface storage.

Expected Ground-Water Developments

Possible ultimate ground-water developments in California include utilization of (*a*) unused ground-water storage to extent of safe yield in ground-water basins not fully developed, and (*b*) increments in safe yield of ground-water basins as additional surface water supplies are made available. A major portion of the water utilization, both surface and ground waters, is within the ground-water basins in the state. The maximum amount of firm water (water that is available on demand) under ultimate development of the state's water resources could be obtained through operation of surface reservoirs, insofar as possible, on an average yield basis in conjunction with cylic underground storage. An adequate supply of energy would be necessary in a series of dry years to pump ground water.

Unused Ground-Water Storage.—The largest body of unused ground-water storage in the state is in the Sacramento Valley. Results of appraisal of geologic feature of Sacramento Valley ground-water basins show over 28,000,000 acre-ft of underground storage capacity within the 20- to 200-ft zone below ground surface underlying 2,066,000 acres in this area. This area will generally support heavy draft pumping. An additional area of about 630,000 acres of basin deposits has an estimated ground-water storage capacity of more than 5,000,000 acre-ft within the same depth zone. The basin deposits are less permeable, and low well yields are generally obtained therein, but determination has not been made of the usable portion of the storage capacity. The Sacramento Valley ground-water basins were fully charged in 1950, except for limited areas in Sutter, Yuba, Placer, and Solano Counties. The total pumpage in the Sacramento Valley in that year was about 1,000,000 acre-ft, and the net draft on ground water for irrigated crops was probably less than half this amount under the prevailing irrigation practices at that time. The safe yield of this extensive ground-water reservoir has not been determined. If average ground-water levels were drawn down about 10 ft below those prevailing in 1950, there would be a great salvage of uneconomic consumption on some 780,000 acres of high-water table land and drainage from the ground-water basin through the stream system.

The unused underground storage capacity in the Camphora-Greenfield area in Salinas Valley, within the 125–ft zone below ground surfact, was estimated to be 575,000 acre-ft in 1946.[2] It was further estimated that utilization of about 130,000 acre-ft of unused storage within the 60-ft zone below ground surface in that area would provide an adequate solution of the ground-water problem in Salinas Valley. Studies have been undertaken of methods of using such unused ground-water storage in conjunction with surface storage to provide a complete solution of flood control and water conservation problems in Salinas Valley under probable ultimate development.

As previously mentioned there was fully recharged underground storage in 1950 in Owens Valley now being held as stand-by for the City of Los Angeles. The City also has substantial stand-by underground storage in San Fernando Valley. Mention is made again of the uneconomic consumption of ground water in Mojave Valley. This water could be salvaged for beneficial uses through full utilization of the unused ground-water storage in that basin.

In addition, similar uneconomic consumption is evident in the ground water underlying about 250,000 acres of high-water table land in the Kings River service area. Greater utilization of ground-water supplies would result in salvage of a substantial portion of such natural disposal.

Intensive ground-water investigations in California prior to 1948 have largely been confined to the areas where overdraft conditions existed.

Increments in Safe Yield.—An essential feature of the Central Valley Project in the San Joaquin Valley is utilization of ground water reservoirs for the storage and subsequent extraction of water supplies by pumping. Underground reservoir utilization is particularly important in the southern

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[2] "Salinas Basin Investigation," *Bulletin No. 52*, Div. of Water Resources, Dept. of Public Works, State of California, Sacramento, Calif., 1946.

San Joaquin Valley where experience has already demonstrated its practicability and value, and where wells and pumping plants with an aggregate capacity of over 25,000 cu ft per sec are in operation.

The usable underground storage capacity in the southern San Joaquin Valley south of Chowchilla totals over 20,000,000 acre-ft, and in the northern San Joaquin Valley about 3,000,000 acre-ft. The Central Valley Project provides full utilization of the underground capacity in the southern San Joaquin Valley with operation thereof coordinated with surface storage regulation. The chief cost involved in the utilization of the underground storage would be for the operation of pumping installations, on which it is estimated a capital outlay of approximately $200,000,000 had been made up to 1950. Augmentation of surface water supplies on the east side of the southern San Joaquin Valley by an average of about 1,500,000 acre-ft annually will increase the safe yield of ground-water basins by the amount of deep percolation from unconsumed irrigation water and from spreading of water for direct replenishment. Net draft of ground water should keep pace with increment in safe ground-water yield to prevent occurrence of drainage problems.

Studies have been made to determine the feasibility of introducing surplus water into empty underground space in wet years. If this procedure is feasible, it is believed the amount of loss in subsurface outflow would be small in a limited period of wet years compared with retention for rediversion. If depth of storage is held to more than 12 ft from ground surface, then uneconomic losses through evapo-transpiration direct from the water table would be insignificant.

As additional surface supplies of water are made available in free (unconfined) ground-water zones (as planned for various ground-water basins in the state), the safe yield of the basins will be increased. This will necessitate increased ground-water utilization, insofar as enhancement of supplies exceeds overdrafts, in order to maintain hydrologic balance between supplies and disposal.

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67	June, 1951	"Model and Prototype Studies of Sand Traps," by Ralph L. Parshall	Nov. 1
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